Technology Development and Application for Energy-Saving and Environmental Upgrades in Chinese Smelters Under New Policies

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Abstract

In recent years, under the new policy background of China's electrolytic aluminium industry, it has become a hot topic how smelters can tailor high-quality technology upgrade plans to find the optimal balance between meeting the new policy requirements and creating good economic benefits, thereby achieving low-carbon and green development. This paper presents the on-site renovation project of a 20-year-old smelter located in Sichuan, China as an example, and discusses some key energy-saving and environmental protection upgrade technologies, integration ideas and application effects in the project. After the upgrade, the smelter achieved its design goals, revitalized its machinery, and achieved high-quality development of the smelter.

Keywords: Aluminium electrolysis, Pot technology upgrade, China's Dual Carbon Policy.

1. Policy Background

1.1 China's Dual Carbon Policy

In September 2020, the Chinese President Xi Jinping announced at the General Assembly of the United Nations that China will increase its nationally determined contribution, adopt more effective policies and measures, and strive to peak its carbon dioxide emissions before 2030, and achieve carbon neutrality before 2060.

In December 2020, the Chinese President Xi Jinping further announced at the climate summit that by 2030, carbon dioxide emissions per unit of GDP would fall by more than 65 percent compared with 2005 levels, and increase its forest stock volume by 6 billion cubic meters; also, non-fossil energy will account for about 25 % of its primary energy consumption, the total installed capacity of wind and solar power will reach over 1200 GW.

1.2 Definition and Statistical Value of Various Electricity Consumptions in Smelters

There are many names for the composition of energy consumption in aluminium smelters, including DC energy consumption per tonne of aluminium, liquid aluminium AC energy consumption, liquid aluminium comprehensive AC energy consumption, aluminium ingot comprehensive AC energy consumption, etc. The definition and statistical value of each kind of electricity consumption are found in Chinese National Standard GB 21346-2022 [1], which has been implemented since January 2024. To facilitate the understanding of various energy consumption indicators, they are summarized in Figure 1.

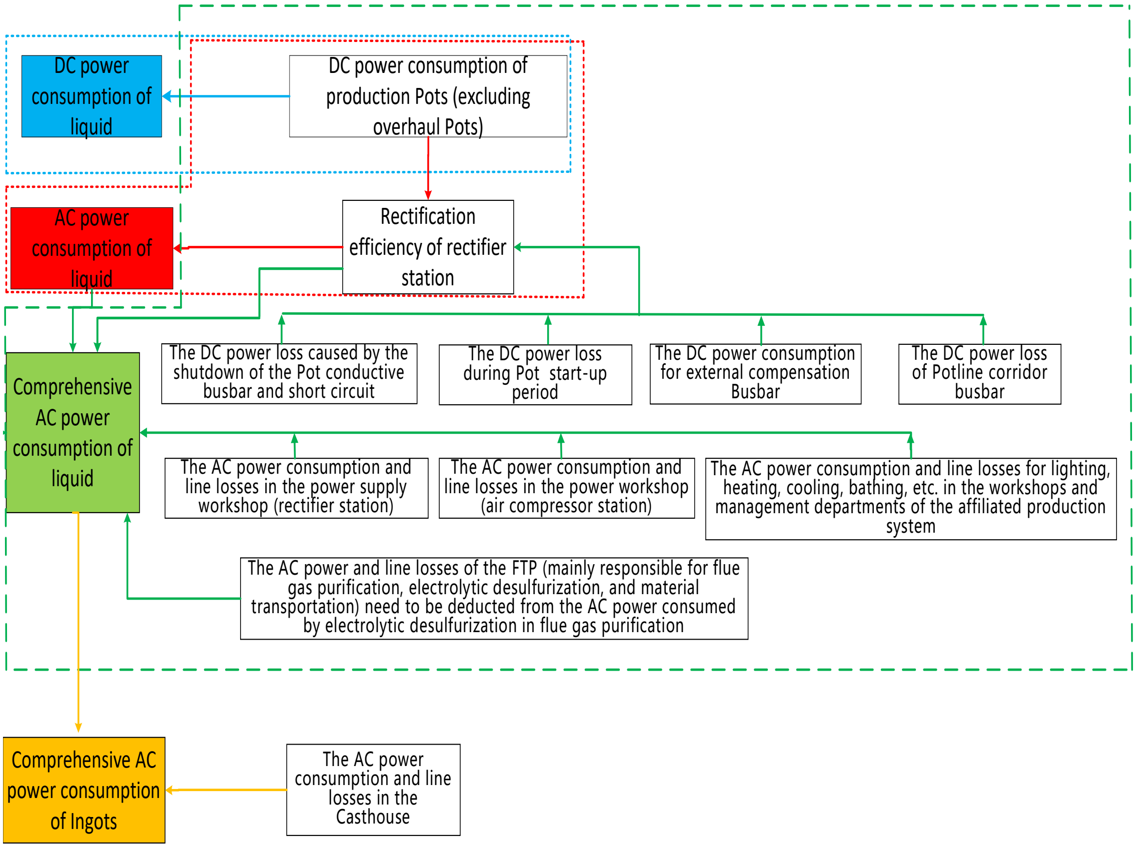

Figure 1. Calculation range of various power consumptions in smelters by Chinese standards.

From Figure 1, it can be seen that the definition range and statistical value of the comprehensive AC power consumption of aluminium liquid are the most practical and valuable.

1.3 Differentiated Stepwise Electricity Charges for Smelters

In August 2021, the National Development and Reform Commission (NDRC) issued and improved policies on differentiated electricity charges for the electrolytic aluminium industry, which encourage aluminium smelters to improve the utilization level of non-hydro renewable energy such as wind power and photovoltaic power generation, and reduce the consumption of fossil energy. To promote energy conservation and emission reduction in the electrolytic aluminium industry, the NDRC has gradually introduced a differentiated electricity consumption policy for the electrolytic aluminium industry; according to its requirements, the comprehensive AC power consumption of hot metal (composed of DC power consumption of pot and auxiliary power consumption in electrolytic aluminium production) in 2022, 2023 and 2025, shall respectively reach to 13 650 kWh/t Al, 13 450 kWh/t Al and 13 300 kWh/t Al. In case of every 20 kWh increase, the electricity price per MWh for production will be increased by 10 yuan, equivalent to 1.3 USD.

1.4 Policy of Benchmark Level and Base Line of Energy Consumption by Smelters

In July 2023, NDRC and other sectors released “Benchmark Level and Base Line of Energy Efficiency in Key Areas of Energy-Intensive Industries” (2023 edition), which has explicitly addressed the proposed and under-construction projects which have to fully implement the Benchmark Level. For the existing smelters, which have operated at a higher level of energy consumption than the Base Line, it is reasonable to set up a transition period for policy implementation, and guide enterprises to carry out energy conservation and carbon reduction technologies in an orderly manner, improve the efficiency of operation, and resolutely shut down outdated production facilities, backward processes and products.

It is clearly stated that the maximum AC energy consumption of hot metal for the electrolytic aluminium industry is 13 000 kWh/t Al for the greenfield, expansion and brownfield aluminium smelters, and 13 350 kWh/t Al for the existing aluminium producers. It is worth noting that the AC energy consumption of hot metal is generally obtained from the DC energy consumption divided by the rectification efficiency of the rectifier.

1.5 Controlling Policy of Energy Consumption Target of Greenfield and Brownfield Aluminium Projects

In [1], energy consumption quota of unit product of electrolytic aluminium and alumina, technical requirements, statistical range and calculation method, are defined for calculations of energy consumption per unit product in electrolytic aluminium and alumina also for the energy consumption of the greenfield, expansion and brownfield projects.

The new rules clearly lay out that maximum energy consumption per unit product for the existing aluminium producers shall be no more than Grade-3, and for the greenfield, expansion and brownfield aluminium smelters, it shall be no more than Grade-2 (see Table 1). The standard was scheduled to be implemented from 1 January 2024.

Table 1. Energy consumption quota standards on unit product of electrolytic aluminium.

Index	Grades of Energy Consumption Quota		
	Grade-1	Grade-2	Grade-3
AC energy consumption of hot metal (kWh/t Al)	≤ 12 950	≤ 13 000	≤ 13 350
Comprehensive AC energy consumption of hot metal (kWh/t Al)	≤ 13 250	≤ 13 350	≤ 13 700
Comprehensive AC energy consumption of ingot (kWh/t Al)	≤ 13 300	≤ 13 400	≤ 13 750

It is understood from the above table that the permitted value of energy consumption per unit product aimed at the greenfield and brownfield electrolytic aluminium smelters shall achieve the Benchmark Level already issued by NDRC in October 2021, i.e., AC energy consumption of hot metal with a maximum of 13 000 kWh/t Al, meanwhile the comprehensive AC energy consumption of hot metal shall also be at a maximum of 13 350 kWh/t Al. For the existing aluminium producers, the base line of AC energy consumption of hot metal shall be a maximum of 13 350 kWh/t Al, meanwhile the comprehensive AC energy consumption of hot metal shall remain under 13 700 kWh/t Al.

1.6 Policy of Emission Reduction as per Environmental Performance in the Heavy Pollution Weather

In China, the Air Quality Index (AQI) level is based on the level of six atmospheric pollutants, namely sulfur dioxide (SO_2), nitrogen dioxide (NO_2), suspended particulates smaller than 10 µm in aerodynamic diameter (PM10), suspended particulates smaller than 2.5 µm in aerodynamic diameter (PM2.5), carbon monoxide (CO), and ozone (O_3) [2]. China identifies weather with AQI greater than 200 as heavy pollution weather [3]. In conformity with the “Technical Guidelines for

Emergency Emission Reduction Measures in Key Industries under the Heavy Pollution Weather" rolled out by the Ministry of Ecology and Environment, all provinces and cities across China are required to implement the "Guidelines", according to regulations. Environment performance of enterprises is categorized as Grade A, B, C, D, among which Grade A enterprises can only implement independent emission reduction under the heavy pollution weather. For Grade B and below enterprises as well as non-leading enterprises, particle emission reduction shall be no less than the requirements of Guidelines.

1.7 Special Action Plan for Energy Conservation and Carbon Reduction in Smelters

On 23 July 2024, the National Development and Reform Commission and five other departments jointly issued the "Special Action Plan for Energy Conservation and Carbon Reduction in the Electrolytic Aluminum Industry" [4]. The plan states that:

By the end of 2025, the proportion of production capacity above the energy efficiency benchmark level in the electrolytic aluminum industry will reach 30 % Production capacity below the energy efficiency benchmark level has been technically transformed or phased out. The industry's renewable energy utilization proportion has reached more than 25 %, and the output of recycled aluminum has reached 11.5 million tonnes.

……

By the end of 2030, the energy consumption and carbon emissions per unit of products in the electrolytic aluminum industry will have dropped significantly, the use of renewable energy will be further improved …

……..

Important breakthroughs have been made, the supply capacity of high-end aluminum products has been greatly improved, and the industry's green and low-carbon development has achieved remarkable results.

This will be achieved through technological upgrades and innovations.

1.8 Summary

From the above, it can be seen that in recent years, in order to regulate the investment and construction order of the electrolytic aluminium industry and respond to the "dual carbon policy", the government has continuously promoted the supply side structural reform of the aluminium industry in response to the overcapacity situation. It encourages and guides low-competitive production capacity to exit the market, consolidates and resolves the achievements of electrolytic aluminium overcapacity, strictly controls the addition of electrolytic aluminium production capacity, strictly implements capacity replacement, strengthens environmental supervision, carries out environmental remediation actions, controls total emissions, and promotes the orderly, low-carbon and healthy development of the aluminium industry.

The government promotes enterprises to improve efficiency and meet standards by setting tiered electricity prices, controlling energy consumption targets for new construction or expansion, setting industry energy efficiency benchmarks, and phasing out outdated production capacity in batches within a specified period of time. This forces the electrolytic aluminium industry to carry out energy-saving and carbon-reduction technology upgrades and accelerate the elimination of outdated production capacity.

After the successive release of various policies, most aluminium smelters have combined their own situations to upgrade and transform their core equipment in order to achieve sustainable development of the enterprise.

Guiyang Aluminium and Magnesium Design & Research Institute（hereinafter referred to as GAMI) has undertaken multiple technical upgrade design tasks for electrolysis projects, all of which have achieved good results [5, 6]. The most prominent one is the energy-saving and environmental performance upgrade project of Sichuan Aostar Aluminum Industry Co., Ltd. (hereinafter referred to as AAC). The project creatively adopted many innovative technologies in the upgrade, which is a benchmark project for China's low-carbon, environmentally friendly and energy-saving aluminium electrolysis technology created by both parties.

2. Engineering Design Background and Indicators

In recent years, various policies have been introduced successively, which have brought certain pressure to AAC. On the one hand, the specific energy consumption of the 300 kA potlines, namely the comprehensive AC power consumption of liquid, was 13 780 kWh/t Al, which cannot meet the requirements of the national energy consumption policy. On the other hand, due to the fact that the smelter was built in 2003 and has been in operation for 20 years, its workshops, floors, dust collection facilities, etc., have suffered significant damage or are relatively outdated, failing to meet the requirements of an environmentally friendly A-level enterprise. In the heavily polluted weather of the region, limited by emission reduction quotas, there is a huge risk of being forced to reduce or stop production by the government.

Figure 2. Map of AAC factory area.

The energy-saving and environmental performance upgrade project of AAC involves the in-situ upgrading of 168 pots in the existing potroom building, which effectively controls project investment. The use of relevant equipment technology is defined as the "upgraded version of 300 kA aluminium electrolysis core technology and environmental performance low-carbon production comprehensive technology".

The upgraded 300 kA potline is an internationally advanced level potline independently developed by GAMI, which has the advantages of lowest energy consumption, lowest emissions, and most efficient land use. The potline current is 300 kA, and the comprehensive AC energy consumption of liquid is below 13 000 kWh/t Al, which saves more than 500 kWh/t Al of energy compared to the national average level. The fluoride emission is < 0.3 mg/Nm^3, the dust emission is < 10 mg/Nm^3, and the SO_2 emission is 35 mg/Nm^3, far below the current national standard of 200 mg/Nm^3, achieving ultra-low emissions and leading the technological progress of the aluminium industry. All technical indicators have reached the international leading level.

The AAC potroom and pots before and after the upgrade are shown in Figures 3–6.

Figure 3. The potroom before the upgrade.

Figure 4. The potroom after the upgrade.

Figure 5. The pot before the upgrade.

Figure 6. The pot after the upgrade

3. Upgraded Version of 300 kA Pot Technology

The upgraded 300 kA pot technology is developed by AAC and GAMI under the support of the "production learning research application" platform, effectively integrating new modes such as "production practice + computer numerical simulation + physical field testing of aluminium electrolysis cells + cloud-based aluminium electrolysis cell design", and adopting many innovative design concepts. Compared with the operating indicators of domestic pots with the same or even larger capacity, its energy consumption, production efficiency, and automation level are leading the industry, saving more than 500 kWh/t Al of energy compared to the national average. It can be regarded as a benchmark model for the design and renovation of electrolytic aluminium projects in China.

The upgraded 300 kA pot core technology is mainly reflected in the following sections.

3.1 Energy Saving 300 kA Pot Technology

Under the national development strategy of "carbon neutrality and peak carbon emissions", the focus is on "energy conservation, carbon reduction, and low-carbon", further optimizing the physical field design of pot magnetohydrodynamic (MHD) stability, electrical and thermal balance. A series of cutting-edge and advanced new materials, processes and equipment in the industry have been industrialized and applied in the upgraded 300 kA pots, achieving multiple innovative results:

(1) Further breakthrough in MHD stability - MHD stability of the pots is a key core technology. By continuously optimizing the two key elements of horizontal current and magnetic field distribution, the horizontal current is minimized, the magnetic field value is reduced, and the magnetic field distribution shape is optimized to further break through the technical bottleneck of MHD stability. This ensures that the pot maintains ultra-high stability and anti-interference ability in both "steady state" and "transient state", thereby achieving the goal of long-term low energy consumption and efficient operation of the pots. It can reduce pot voltage drop by 40 mV.

(2）Reduce the voltage drop of the anode conductors and carbon block - The upgraded 300 kA pot has changed the original double anode on a rod to a single anode on a rod, minimizing the current path in the pot. At the same time, the anode stub and stub-hole structure have been further optimized to increase the steel-carbon contact area and reduce the steel-carbon voltage drop.
For the key connection between the anode rod and the yoke, traditional explosion welding clads are eliminated and aluminium-steel direct welding technology is adopted. Advanced fully automated robot welding equipment is introduced to ensure good welding quality.

In addition, fully leveraging the advantages of having a carbon plant in the smelter:

1) The quality of anode carbon blocks from the source of raw materials was improved and
2) Advanced and efficient anode slotting equipment was introduced, thus further optimizing the slotting method, increasing the slot depth, and reducing the bubble voltage drop.

Taking all the above factors into consideration, the voltage drop was reduced by 31 mV. Figures 7–8 show modelled anode voltage drop.

(3) Reduce voltage drop of the busbar system - Optimize the configuration and cross-sectional dimensions of the potline and pot busbars, reduce the voltage drop of the busbar system by 35–40 mV per pot.

(4) High conductivity busbar technology - By using highly conductive busbars, the conductivity of the aluminium busbar system has been improved, effectively reducing the resistance of the busbar system, lowering the voltage drop of the busbar system by 6 mV.

(5) Balanced aluminium flow pot technology - By adjusting the insulation structure and upgrading the lining material, matching and optimizing the adaptive thermal balance design of the pot, a sturdy cathode is designed, allowing pot voltage reduction of 83 mV.

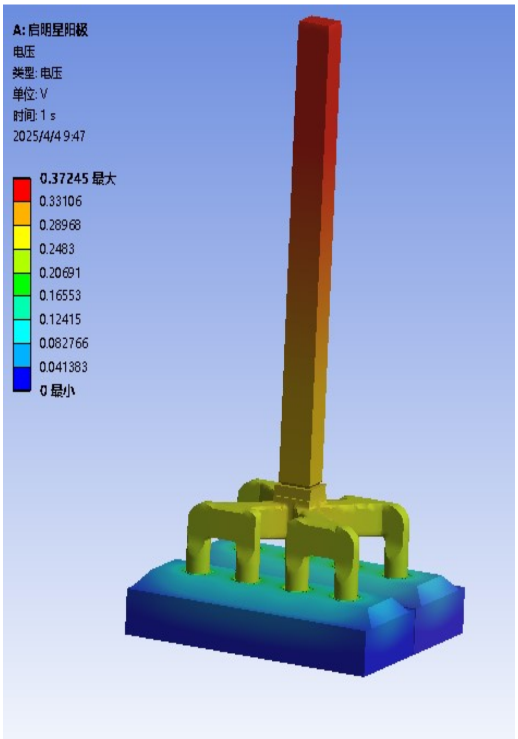

Figure 7. Double-anode voltage drop.

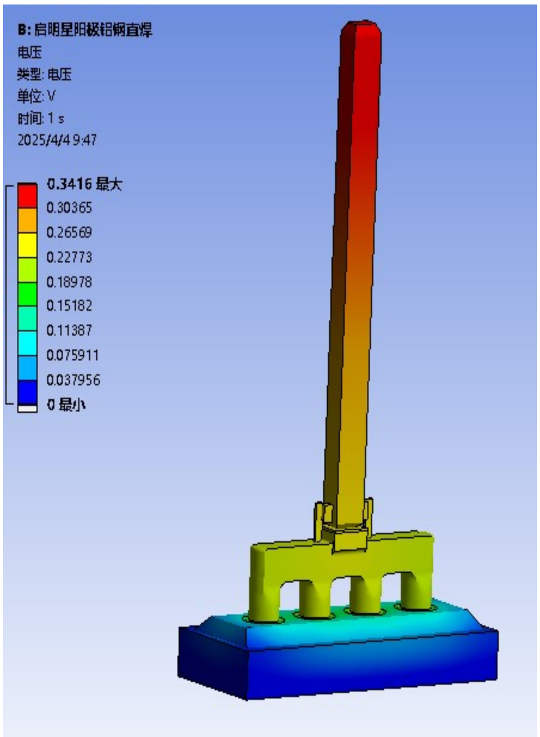

Figure 8. Single-anode voltage drop.

3.2 300 kA Pot Technology with Long Life Guarantee

By using the upgraded cathode assembly method, the horizontal current in the liquid aluminium is significantly reduced, improving the operational stability of the pot. At the same time, efforts are made to slow down the electrochemical erosion rate caused by current density concentration in the pot and improve the service life of the cathode.

In terms of lining and insulation materials, by upgrading key materials, improving physical and chemical parameter requirements, comprehensive supervision and sampling, the insulation and anti-seepage performance of the cathode bottom is enhanced, and the erosion rate of the lining insulation performance is slowed down by about 40 %.

Further upgrade and strengthening of the integrated welding of cradle and shell structure, including innovation of the self-locking cradle-shell structure, the strength and stiffness of the cradle-shell as a whole was increased; this effectively limited the potshell deformation during the life of the pot, and ultimately achieved a maximum vertical deformation to no more than 2 cm during pot preheat and start-up.

3.3 Low-Carbon and Environmentally Friendly 300 kA Pot Technology

According to the energy balance test of a 300 kA pot, it is known that the heat loss using a regular cell cover is equivalent to around 250 mV, accounting for 25 % of the upper heat loss. By adopting a new energy-saving insulation cover, the insulation can be increased without increasing its weight. This can effectively reduce the heat dissipation of the cover by 9 mV, and significantly improve the energy consumption and environmental protection of the pot.

In order to effectively save project investment and consider the recycling of materials, the original superstructure has been partially renovated, adopting the upper flue gas collection form, equalizing the negative pressure under the hood, improving the pot gas collection rate, reducing the exhaust volume of each pot and the energy consumption of the scrubbing system. In response to the characteristic of doubled exhaust volume during anode change operation, a dual exhaust duct system is adopted, which can effectively increase the gas exhaust volume of a single pot and facilitate automatic pressure balance between pots, thereby reducing uncontrolled gas emissions during anode change and improving the efficiency of the scrubbing system. The old and the new designs are shown in Figures 9–10.

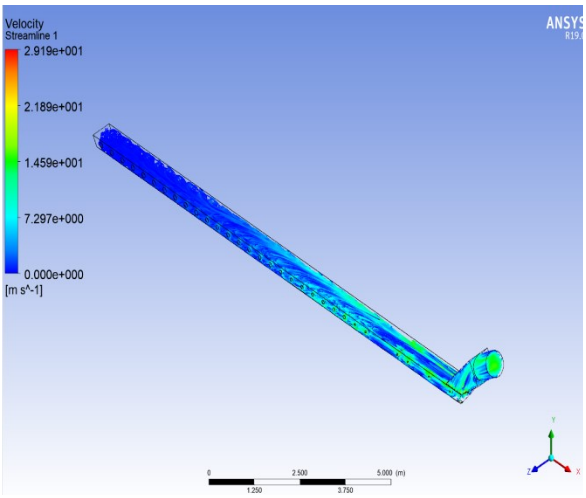

Figure 9. Old design flue gas streamlines.

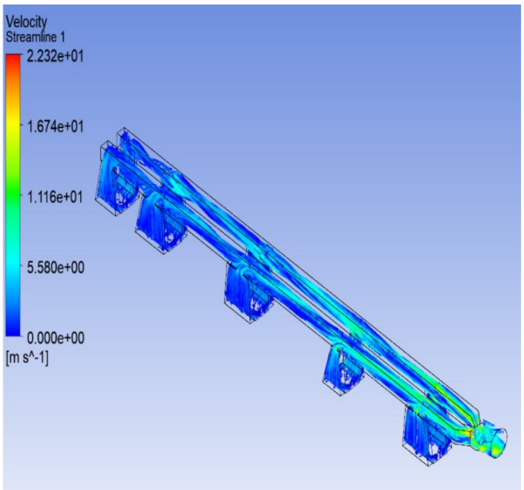

Figure 10. New design flue gas streamlines.

3.4 Intelligent Pot Control in 300 kA Pot Technology

The multi parameter pot control technology of GAMI is adopted, with computer control as the core, to achieve dual balance control of energy and material in the pot:

1) By establishing technical management standards for pots and adjusting various technical conditions to achieve a stable and orderly pot state;
2) By using pot voltage, conditional control of aluminium fluoride addition, and computer aluminium output indication, the optimization control of superheat and excess aluminium fluoride can be achieved, thereby improving current efficiency and energy consumption. Under constant external conditions, the current efficiency can be effectively improved by about 0.5–1 %.

By adopting intelligent point crust breaking and feeding technology, the status of the feeding hole is determined, and the depth and frequency of crust breaking are automatically adjusted. Compared with traditional crust-braking systems, it can reduce the compressed air consumption by 70 %. At the same time, due to the precise control of the alumina feeding amount, the pot voltage drop can be reduced by 10 mV.

4. Upgraded Version of 300 kA Pot Comprehensive Supporting Technology

4.1 Energy-Saving Retrofit Technology for Rectifier Units

AAC Phase I transformer was purchased in 2003, and the current rectification efficiency is 97.66 %. Due to the technological level and material limitations at that time, there was a certain technological gap between equipment such as rectifier transformers and rectifier cabinets and current advanced products. This is one of the main reasons why the power supply efficiency of aluminium plants is lower than 98 %. On the other hand, the difference between product design parameters and actual operating data is also a reason for the overall increase in energy consumption, while significantly increasing operating costs.

By using advanced rectifier transformers and rectifiers, coupled with modifications to the busbar, the rectification efficiency can be increased from 97.66 % to 98.3 %, reducing the specific AC energy consumption by at least 80 kWh/t Al.

Figure 11. The old rectifier unit.

Figure 12. The new rectifier unit.

4.2 Energy Saving Technology for Intensive Layout of Air Compression Station System

Concentrate the air compression station between two potrooms, so that the gas source is as close as possible to the maximum gas consumption point in the plant, reducing pressure loss in the pipeline network. After the relocation, all the air compressor station buildings were newly built, and all the equipment was rearranged. The original air compressor was relocated and reused, and the original centrifugal air compressor will be renovated. The compressed air dryer was selected as a waste heat regeneration adsorption dryer, which uses the compression heat of the air compressor to regenerate the adsorbent, fully saving energy and ensuring the quality of compressed air. After the relocation of the screw air compressor, a blast heat regeneration dryer is selected as the supporting compressed air dryer to ensure consistent compressed air quality.

The new air compression station still supplies air to the carbon production area.

After the intensive layout of the air compression station, the electricity consumption can be reduced by about 8 kWh/t Al.

4.3 Energy-Saving Retrofit Technology for Potline Flue Gas Purification Fan

Originally, each set of Fume Treatment Plant (FTP) used 4 centrifugal fans running in parallel, with each fan motor of 630 kW, which had low efficiency. In order to reduce the energy consumption of the gas exhaust fans, one centrifugal fan was removed after upgrading and renovation, and one static blade adjustable axial flow fan was added. Normally, one axial flow fan runs, and the other 3 centrifugal fans are used as backups.

The static blade adjustable axial flow fan can adjust the air volume and pressure by adjusting the inlet guide vanes, with a wide adjustable range and high mechanical efficiency. It is suitable for high flow conditions and can reduce the energy consumption by 20 kWh/t Al.

5. Comprehensive Technologies for Low Carbon Production with Environmental Performance

5.1 Limestone Gypsum Wet Desulfurization Environmental Protection Technology

The AAC Potline 1 flue gas purification system uses limestone gypsum wet desulfurization technology. This technology is currently the most widely used and reliable process in the world. The process uses limestone slurry as an absorbent to wash the flue gas in the absorption tower through limestone slurry, and a reaction occurs to remove SO_2 from the flue gas. The calcium sulfite produced by the reaction is forcibly oxidized to produce calcium sulfate (gypsum) containing two crystal waters.

The Potline 1 flue gas purification system of this project uses efficient purification technology and greatly improves production operation control technology, which can achieve fluorine purification efficiency of over 99.5 %, SO_2 purification efficiency of over 80 %, and pot gas collection efficiency of over 99.5 %.

5.2 Distributed Butt-Cooling Environmental Protection Technology

In order to meet the requirements of national policy, the butts in the potrooms need to go through processes such as cooling, transportation, temporary storage, and then transportation to the anode rodding shop after leaving the pot. For each process link, targeted equipment and facilities are adopted to meet policy requirements.

A certain number of distributed butt-cooling devices are installed on the tap end of the pots (Figure 13). Once the butts leave the pot and are placed in the nearest tray on the tap end, the butt-cooling device will automatically seal and cover the tray. At the same time, it opens the exhaust interface to collect and extract the smoke emitted by the butts in a timely manner, reducing uncontrolled emissions in the potroom and ensuring clean potroom environment.

Figure 13. Distributed butt cooling device.

5.3 Centralized Butt-Cooling Environmental Protection Technology

To further improve the collection capacity of butt flue gas cooling in the potrooms, compensate for the scattered distribution of distributed butt-cooling and the difficulty in dealing with peak anode changing periods, and more reliably ensure the potroom environment. At the end of the potrooms, two enclosed butt-cooling zones are innovatively set up as auxiliary facilities for distributed butt-cooling devices. Incompletely cooled butts can be placed in these enclosed rooms, and the flue gas can be promptly extracted through the exhaust interface connected to this area.

There is a cold anode storage area located nearby, which is closed to the butt-cooling area through an automatic rolling shutter door. To ensure the sealing effect of the butt-cooling area, the rolling shutter door is usually closed. When vehicles carrying cold anodes need to enter and exit the cold anode storage area, the rolling shutter door automatically opens.

Figure 14. Centralized butt-cooling device.

5.4 Cleaning Technology for Concealed Corners of Equipment in the Potroom

According to the "Technical Guidelines for Emergency Emission Reduction Measures in Key Industries with Heavy Pollution Weather", the potroom shall not adopt cleaning measures that are prone to dust generation such as compressed air blowing, and the pot shall not have obvious smoke and dust emissions.

To meet the requirements of the national technical guidelines, the project is equipped with an industrial tank type suction truck with a maximum suction distance capacity of about 100 meters. It is used to vacuum and clean some equipment and facilities in the workshop, such as pots, overhead cranes, and other dust prone areas, to better meet the requirements of achieving Grade A-level environmental protection (ACA) (see Section 1.6).

5.5 Centralized and Efficient Pot Relining (Overhaul) Technology

The project uses centralized and efficient pot relining technology, which avoids the adverse environmental impact in the potroom caused by de-lining and relining of pots in the potrooms, which creates a lot of toxic dust and noise. The new pot relining center outside the potrooms better meets the requirements of ACA. This technology lifts the pot cathode that needs to be relined and transfers it from the potroom to the pot relining center where it will be de-lined and relined in a closed space. At the same time, a ready, spare relined cathode is picked up in the pot relining center and taken back to the potrooms.

The spare pots can be quickly installed, energized, and put into operation. This technology greatly shortens the relining cycle of pots, significantly improves the operating time of pots, and provides reliable guarantees for the efficient operation and production capacity compliance of the smelter.

5.6 Pot Tending Machine (PTM) Overall Efficient Transportation Technology

By using the track lifting device and transfer overhead crane shared by the potrooms and the pot relining workshop in the centre passage, the PTM can be flexibly switched between the two potrooms and the pot relining centre quickly and reliably.

This technology can achieve centralized repair of PTM and flexible allocation of PTMs in extreme production situations in the potrooms, thereby providing reliable guarantees for the efficient operation and environmental performance of the potrooms.

6. Potline Performance

The original smelter was started up in 2005, and the upgraded smelter was started up in October 2024. The potline key performance indicators (KPIs) before and after the upgrade are given in Table 2. We can see that the KPIs of upgraded technology are largely improved: Current efficiency increased by 1 %, comprehensive AC energy consumption of hot metal decreased by 822 kWh/t Al, net carbon consumption decreased by 5 kg C/t Al, Fe level decreased by 0.07 percentage points and anode effect frequency was brought down to 0.06 AE/pot·day. Particularly remarkable is the low DC energy consumption of 12 390 kWh/t Al, which is at world leading level.

Table 2. Potline key performance indicators (KPIs) before and after the upgrade.

Parameter	Unit	Before upgrade	After upgrade
Amperage	kA	296	300
Current efficiency	%	91.6	92.6
Metal production	kg/pot·day	2183.2	2236.8
Net pot voltage (pot-to-pot)	V	4.01	3.85
Specific DC energy consumption	kWh/t Al	13 046	12 390
Comprehensive AC energy consumption of hot metal	kWh/t Al	13 780	12 958
Net carbon consumption	kg C/t Al	410	405
Gross carbon consumption	kg C/t Al	494	478
Fe	%	0.15	0.08
Si	%	0.040	0.035
Anode effect frequency	AE/pot·day	0.30	0.06
Anode effect duration	s	252	222

7. Conclusions

GAMI adheres to the basic principle of "creating maximum benefits for aluminium enterprises, spending small money, and doing big things", and combines with the unique situation of smelters to upgrade and transform the smelter in a targeted manner. The upgraded and transformed AAC project has a comprehensive AC power consumption of aluminium liquid below 13 000 kWh/t Al, and the operating KPIs are excellent, fully meeting or even exceeding the highest standard required by China's electrolytic aluminium energy consumption policy, and Environmental Innovation A is steadily advancing.

The "high-quality technological upgrading" model used by GAMI has found the best balance between meeting new policy requirements and creating good economic benefits for smelters, achieving sustainable development and gaining satisfaction and recognition from aluminium smelters. GAMI is willing to share and exchange ideas with domestic and foreign peers, make progress together, and strive for the sustainable development of the world's electrolytic aluminium industry.

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